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REPUBLIC OF KENYA

MINISTRY OF AGRICULTURE—NATIONAL AGRICULTURAL LABORATORIES

KENYA SOIL SURVEY

DETAILED SOIL SURVEY OF AN EXPERIMENTAL SITE FOR THE BURA IRRIGATION SETTLEMENT PROJECT

by

E. N. K. Mugai and B. J. A. van der Pouw

DETAILED SOIL SURVEY REPORT No.D12, 1978

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<u>Table of contents</u>	<u>Page</u>
1. Introduction	1
2. Working method	1
3. Results	2
3.1. Research areas of Bura Irrigation Settlement Project	2
3.2. Experimental Site in the Hola Irrigation Project	3
4. Conclusions	5
5. Acknowledgements	5
6. References	6

Appendices

App. 1 Representative profiles of Bura and Chewele Branch Canal Research Areas	7
App. 2 Representative profiles of the experimental site in the Hola Irrigation Project	16

Figures

after page

Fig. 1 Detailed soil map of the proposed experimental site, Hola	3
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1. INTRODUCTION

The planned Bura Irrigation Settlement Project will start research on some soil units, including the units S2, N42 and GU2 (Sir M. MacDonald and Partners, 1977) to investigate their suitability for irrigated agriculture. The soils of these three units have a shallow (i.e. less than 20cm thick) non-saline, non-alkali topsoil and were therefore largely excluded from the first phase of the Bura Irrigation Settlement Project area. The future research areas however have already been marked on the irrigation lay-out (op.cit.).

In order to gain time, the National Irrigation Board wants to start experiments this year on a site near Hola, on soils comparable to those occurring in the research areas of the Bura Irrigation Settlement Project. Consequently the Kenya Soil Survey was requested to carry out a detailed soil survey of the site near Hola, comprising 50 ha just north of the Extension Area of the Hola Scheme, and to compare these soils with those in the future research areas of the Bura Irrigation Settlement Project.

2. WORKING METHOD

Prior to the detailed survey of the site near Hola, the soils of the future Bura research areas were studied. Two research areas were selected namely one in the area commanded by the Bura Branch Canal (north of the L. Hiranman) and another one in the area commanded by the Chewele Branch Canal (south of the L. Hiranman).

The soil map of the area north of L. Hiranman (ILACO, 1975) was used to locate 5 profile pits in the Bura Branch Canal research area, as follows: 2 pits in unit GU1, 2 pits in unit GU2 and one pit in unit S2.

According to soil maps for the area south of L. Hiranman (ILACO, 1977), the Chewele Branch Canal research area largely consists of soils belonging to unit S2. Therefore only 2 profile pits were dug in this area.

All profile pits were examined in detail and described according to KSS - standards.

...../2

After that the detailed soil survey of the experimental site near Hola was carried out. Observations were done in a 100m - grid and consisted alternatively of deep (130 cm) and shallow (70cm) pits, totalling 50. All pits were described according to KSS standards and filed in the KSS data storage.

During the fieldwork electrical conductivity measurements were done on samples from all horizons (ratio soil: water = 1:2.5). Ten representative profiles were sampled for standard analysis by the NAL routine laboratory. Their distribution is as follows:

Bura Branch Canal research area:	3 profiles	(see app. 1)
Chewele " " " " :	1 profile	(see app. 1)
Experimental site near Hola	: 6 profiles	(see app. 2)

3. RESULTS

3.1. Research Areas of Bura Irrigation Settlement Project

A. Bura Branch Canal Research Area

In this area five profile pits were investigated. Two pits were situated in a part previously mapped as GU1 and indeed proved to be GU1 soils. A typical profile (no. Bura - 1), with analytical data⁺, is given in appendix 1.

Two other pits were located in a part mapped as GU2. One was indeed a GU2 soil, but the second pit showed a typical N42 - soil. The GU2 - soil⁺ (no. Bura - 3) is described in appendix 1.

Finally, the last pit, dug in an area mapped as S2, showed again a typical N42-soil. This profile⁺ (no. Bura - 5) is also described in appendix 1.

For a detailed description of GU1 and GU2 soils reference is made to existing reports (see References). Here it will only be mentioned that both units comprise reddish brown to brown cracking clay soils with a slight gilgai micro-relief, a crumbly topsoil and a saline and sodic subsoil with slicken-sides. Unit GU1 comprises the soils with a non-saline non-alkali topsoil of more than 20cm thickness, while unit GU2 comprises those soils with ~~ann~~-saline, non-alkali topsoil of less than 20cm thickness.

Unit ~~N42~~ is described in ch. 3.2.

+ see footnote on page 3.

B. Chewele Branch Canal Research Area

The investigation of the two profile pits in this area confirmed the occurrence of soils of unit S2 as indicated by the existing soil maps (op.cit.). A typical profile⁺ (no. Chew. - 1) is described in appendix 1. Unit S2 is described in ch. 3.2.

3.2. Experimental Site in the HOLA Irrigation Project.

The soils of the **experimental** site near Hola belong to three units described in previous reports (ILACO, 1975 and 1977) namely S2, N42 and N3. However, due to the detailed nature of the observations (only profile pits) some subdivision could be made. Unit S2 was subdivided into S2 proper and S2c, and unit N42 into N42 proper and N42s. Moreover two soil units transitional between N42 and N3 could be distinguished (see also fig. 1).

Brief description of the units

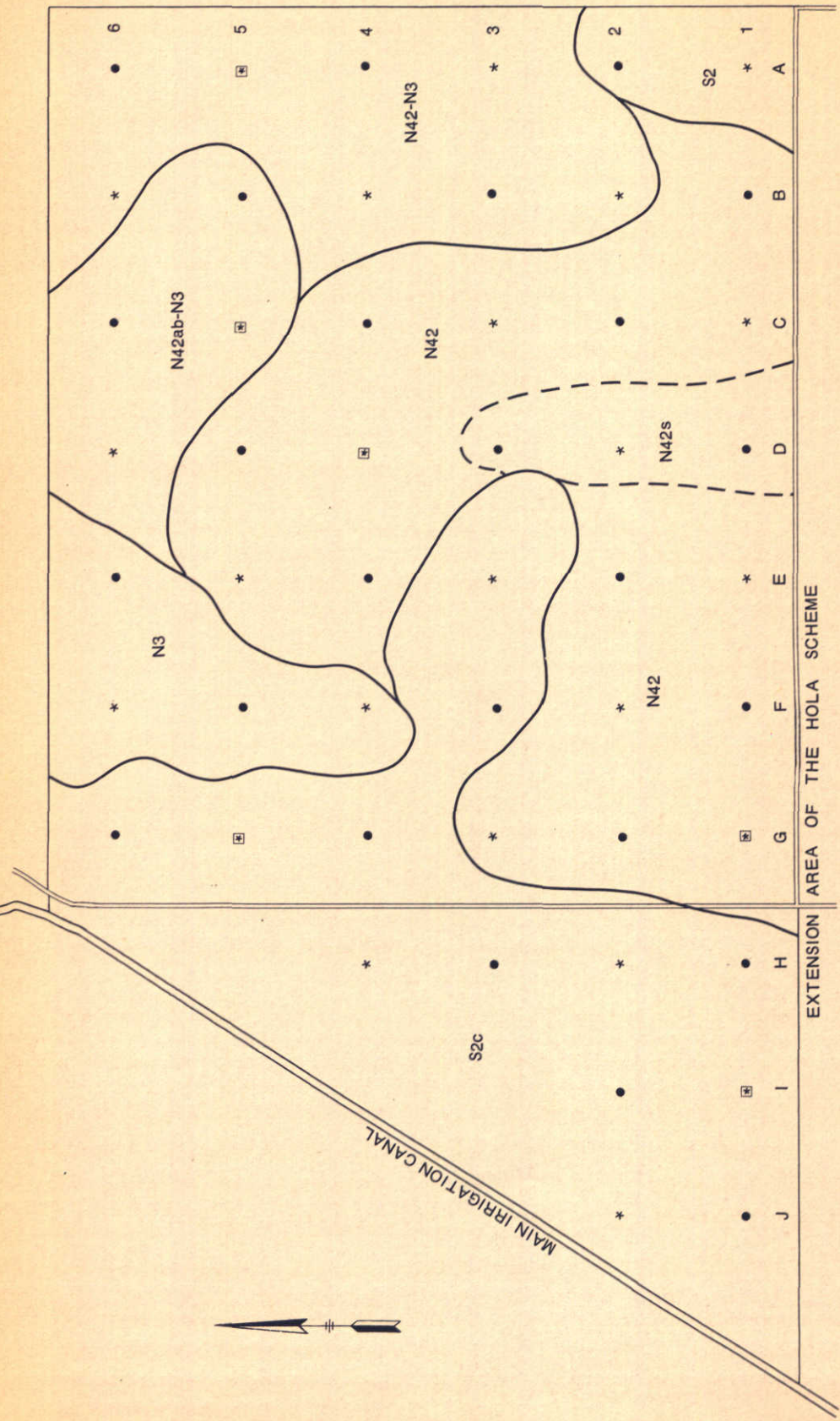
Unit S2

The soils of this unit have a non-saline, non-alkali topsoil of 10-15cm depth, directly followed by a saline-alkali subsoil. The salinity level is quite high, usually reaching about 8 mmhos/cm (1:2.5 suspension) at 80cm depth.

The soils are clayey throughout, but usually with a slightly lower clay% in the topsoil. The topsoil has a fine crumb structure, whereas the subsoil shows a compound angular blocky structure. The upper part of the subsoil (B-horizon) may have a very weak prismatic structure. The soils are strongly calcareous throughout. In previous reports (ILACO, 1975 and 1977) the soils have been classified as "Typic Halorthids".

+ With respect to the analytical data presented in appendices 1 and 2 it has to be mentioned that for some determinations, particularly CEC, exchangeable Na and exchangeable sodium percentage (ESP), very conflicting results were obtained. Repeats did not clarify this. Therefore in some instances estimates had to be given. The low reliability of a considerable number of results is indicated by a question mark.

Fig. 1 DETAILED SOIL MAP OF THE PROPOSED EXPERIMENTAL SITE, HOLA



LEGEND

- S2 typical Halorthids
- S2c like S2, but with a weak surface crust
- N42 vertic Natrargids
- N42s like N42, but saline in upper part of B-horizon

- N3 mastic Natrargids
- N42-N3 like N42, but with strong crust as in N3
- N42ab-N3 like N42-N3, but with angular blocky structure in B-horizon

KEY

- road
- soil boundary
- uncertain soil boundary
- shallow pit
- deep pit
- representative deep pit with detailed soil chemical analyses

Unit S2c

Like unit S2, but usually with a weak surface crust of about 4cm thickness. Two representative profiles are described in appendix 2, viz. field ref. I1⁺ and G5⁺. The latter is less typical because of low ESP and EC_e values in the upper part of its B-horizon (14-25cm).

Unit N42

The soils of this unit are characterized by a non-saline, non-alkali topsoil of about 10-15 cm depth followed by a B-horizon of which the upper part (about 15cm) is non-saline and alkali and the rest saline and alkali.

Salinity increases rapidly with depth and the EC_e usually reaches a value of about 10 mmhos/cm at about 50cm depth.

The topsoil has a fine crumb structure, but the subsoil has a weak to moderate prismatic structure composed of angular blocky elements. The soil surface shows little or no cracking, but the subsoil shows moderate cracking in the upper part and common slickensides at greater depth.

The soils are strongly calcareous throughout and often show pockets of soft lime in the subsoil.

Previously (op.cit.) these soils have been classified as "Vertic Natrargids". For typical profiles see field ref. D4⁺ and G1⁺ in app.2. The latter shows comparatively low EC_e values.

Unit N42s

Like unit N42, but also saline-alkali in the upper part of the B-horizon.

According to their salinity, the soils would belong to unit S2, but as their main morphological characteristics are comparable to soils of unit N42, this subunit of N42 was defined. The boundary of this unit is somewhat arbitrary.

*see footnote on page 3

Unit N3

The soils of this unit are characterized by a very shallow non-saline, non-alkali, non-calcareous crust directly over the lower subsoil, the topsoil and upper part of the subsoil being eroded away. Consequently extremely high salinity and alkalinity levels are found directly below the surface crust. This is also expressed by the occurrence of many clusters of salt crystals.

The subsoil has a fine to medium angular blocky structure, sometimes with a weak prismatic superstructure. The subsoil is strongly calcareous throughout.

The soils have been classified as "Mazic Natrargids" (op.cit.).

Unit N42 - N3

The soils of this unit are comparable to normal N42 soils, but they have a moderately strong, 3-5cm thick, non-calcareous surface crust with some sand overwash. A representative profile, field ref. A5⁺, is described in appendix 2.

Unit N42ab - N3

This unit is comparable to the previous one but for the subsoil, which has an angular blocky structure. A typical profile, field ref. C5⁺, is given in app.2.

4. CONCLUSIONS

1. The soils of the investigated research areas of the Bura West Irrigation Project belong to the units GU1, GU2, N42 and S2.
2. The soils of the proposed experimental site near Hola belong mainly to the units S2 and N42.
3. The S2 and N42 soils of the Bura research areas are very similar to the S2 and N42 soils of the proposed experimental site near Hola.

5. ACKNOWLEDGEMENTS

The short notice on which this survey was carried out was made possible by the transport facilities provided by the N.I.B. and by the assistance of Mr. van der Vliet who ~~determined~~ the exact location of all profile pits. Thanks are also due to Mr. Hinga who supervised the analyses of the soil samples by the NAL-laboratory.

⁺ see footnote on page 3

6. REFERENCES

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2. ILACO, 1968, Galole Pilot Demonstration and Training Project:
Soil Survey 1:10,000
3. ILACO, 1973 Tana River Feasibility Studies: the Bura Area. (no additional soil studies)
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5. Kenya Soil Survey, 1976 Soil Correlation in the Bura - Hola Area. Internal Document presented to NIB - IBRD meeting of Oct. 1976.
6. ILACO, 1977, Bura Irrigation Scheme Soil Survey Report (with soil maps at scale 1:10,000 of areas south of L. Hiranman, 42 sheets).
7. Sir M. MacDonald & Partners, 1977 Project Planning Report Bura Irrigation Settlement Project. Vol. 2, Soils Annexe and Agricultural Planning Annexe.

Appendix 1

REPRESENTATIVE PROFILES

OF

BURA AND CHEWELE BRANCH CANAL RESEARCH AREAS

SOIL ANALYTICAL DATA

Bura Branch Canal Research Area

Field Ref. Bura - 1

Unit GU1

Depth in cm	0-20	20-33	33-60	60-100	100-12
Lab No./78	2056	2057	2058	2059	2060
Sand %	26	22	20	18	40?
Silt %	12	16	14	16	12
Clay %	62	62	66	66	48?
Texture class	C	C	C	C	C
pH-H ₂ O 1: 2½ suspension	8.9	8.5	8.8	8.4	8.4
pH-KCl 1: 2½ "	7.0	7.1	7.2	7.1	7.2
EC (mmhos/cm) 1:2½ "	0.35	2.15	2.40	6.50	7.00
CaCO ₃ %	2.6	5.2	2.9	2.3	2.1
CaSO ₄ .2H ₂ O %	tr	0.06	0.14	0.80	tr
C %	0.35	0.24	0.26	0.38	0.24
N %	0.05	0.04	-	-	-
Saturation %	-	66.5	71.8	57.1	119.8
ECe (mmhos /cm)	-	7.50	9.00	26.0	24.0
pH - paste	-	7.7	7.1	7.7	7.3
CEC (me/100g soil)	39.5	34.3	34.0	36.0	31.4
Exchangeable cations:					
Ca (me/100g soil)	57	59	58	47	30
Mg "	3.3	3.4	3.2	3.3	3.6
K "	2.7	2.6	2.6	2.5	2.1
Na "	3.9	7.9	12.8	19.5?	20.3?
Base saturation	100+	100+	100+	100+	100+
ESP	9.9	23	38	54?	65?
Qualitative CaCO ₃	+++	+++	+++	+++	+++
Mehlich analysis:					
Available Na (me/100g soil)	1.65	7.0	-	-	-
" K "	0.44	0.20	-	-	-
" Ca "	22.0	19.2	-	-	-
" Mg "	9.6	10.4	-	-	-
" Mn "	0.38	0.28	-	-	-
" P (ppm)	60	40	-	-	-

Mapping unit GU1

prof. no. Bura - 1

A1 0-20cm

Brown to dark brown (7.5YR 5/4 dry, 7.5YR 4/4 moist) clay; porous massive to weak, fine to medium, crumb structure; friable when moist, sticky and plastic when wet; many very fine and few fine pores; strongly calcareous and non-saline; clear and smooth transition to:

B21 20-33cm

Dark reddish brown (5YR 3/4 dry and moist) clay; strong coarse to very coarse, angular blocky structure breaking into moderate, very fine to medium, angular blocky structure; very hard when dry, firm when moist, sticky and plastic when wet; few, weak slickensides; common very fine pores; strongly calcareous and slightly saline; clear and smooth transition to:

B22 33-60cm

Dark reddish brown (5YR 4/3 dry, 5YR 3/4 moist) clay; moderate, coarse to very coarse, angular blocky structure breaking into weak to moderate, very fine to medium, angular blocky structure; consistence and slickensides as above; few, very fine and fine pores; calcareousness, salinity and transition as above:

B23_{sa} 60-100cm

Dark brown (7.5YR 3/3, dry and moist) clay; structure and consistence as above; common, weak slickensides; few, very fine and fine pores; strongly calcareous and strongly saline, with many small clusters of NaCl crystals; gradual and smooth transition to:

B24sa 100-120cm

Dark brown to dark greyish brown (7.5 YR 3/2 to 10YR 4/2, dry and moist) clay; structure and consistence as above; common to abundant, moderate slickensides; few, very fine pores; calcareousness, salinity and salt crystals as above.

Remarks:

- 1) many, 2-4cm wide cracks at surface
- 2) 0-33cm; many very fine roots
33-60cm; few, very fine roots
60cm+: very few very fine roots
- 3) on the ILACO - map this profile is also included in unit GU1

SOIL ANALYTICAL DATA

Bura Branch Canal Research Area

Field Ref.: Bura - 3

Unit GU2

Depth in cm	0-13	13-32	32-52	72-115
Lab. No./78	2036	2037	2038	2039
Sand %	54	24	30	20
Silt %	10	12	12	16
Clay %	36	64	58	64
Texture class	SC	C	C	C
pH-H ₂ O 1:2½ suspension	9.0	8.8	8.7	8.7
pH-KCl 1: 2½ "	7.4	7.4	7.3	7.4
EC (mmhos/cm) 1:2½	0.40	1.15	2.90	8.50
CaCO ₃ %	1.6	2.4	3.6	2.4
CaSO ₄ .H ₂ O %	tr	0.02	0.14	tr
C %	0.70	0.61	0.53	0.56
N %	0.05	0.05	-	-
Saturation %	-	-	-	-
ECe (mmhos/cm)	-	-	13.0	26.5
pH - paste	-	-	8.3	7.5
CEC (me/100g soil)	30.6	24.8?	22.6?	25.4?
Exchangeable cations:				
Ca (me/100g soil)	42	42	25	42
Mg "	4.8	3.7	2.5	1.9
K "	1.3	1.1	1.1	1.7
Na "	2.0	8.0	7.6?	6.8?
Base saturation	100+	100+	100+	100+
ESP	6.6	32	34?	27?
Qualitative CaCO ₃	++	+++	+++	+++
Mehlich analysis:				
Available Na (me/100g soil)	1.40	4.30	-	-
" K "	0.32	0.22	-	-
" Ca "	15.2	14.0	-	-
" Mg "	9.2	8.8	-	-
" Mn "	0.30	0.34	-	-
" P (ppm)	58	63	-	-

Mapping unit GU2

prof. no. Bura - 3

- A1 0-13cm Brown to dark brown (7.5YR 4/4 dry and moist) sandy clay; weak, very fine, crumb structure; moderately calcareous and non-saline; clear and smooth transition to:
- B21 13-32cm Dark reddish brown (7.5YR 4/4 dry, 5YR 3/4 moist) clay; moderate to strong, coarse, angular blocky structure breaking into moderate, fine to medium, angular blocky structure; hard when dry, firm when moist, sticky and plastic when wet; common, very fine and fine pores; strongly calcareous and non-saline; clear and wavy transition to:
- B22 32-72cm Dark brown (7.5YR 4/3 to 7.5YR 4/2 dry, 7.5YR 3/3 moist) clay; strong, coarse to very coarse, angular blocky structure breaking into moderate, very fine to medium, angular blocky structure; very hard when dry, firm when moist, sticky and plastic when wet; few, weak slickensides; few, very fine pores; strongly calcareous and moderately saline; gradual and smooth transition to:
- B23sa 72-115cm Dark brown to dark greyish brown (7.5YR 3/3 dry, 7.5YR 3/2 to 10YR 4/2 moist) clay; moderate to strong, coarse to very coarse, angular blocky structure breaking into weak to moderate, very fine to medium, angular blocky structure; very hard when dry, firm when moist, sticky and plastic when wet; abundant, moderate slickensides; few, very fine pores; strongly calcareous and strongly saline with common, small clusters of NaCl crystals.

Remarks: 1) 1-3mm thick, very weak surface sealing
2) many, 2-4cm wide cracks at surface
3) 0-32cm: common very fine and fine roots;
32cm + : very few very fine roots
4) on the ILACO - map this profile is also included in unit GU2

SOIL ANALYTICAL DATA
Bura Branch Canal Research Area

Field Ref.: Bura - 5

Unit N42

Depth in cm	0-16	16-38	38-65	65-85	85-130
Lab. No./78	2066	2067	2068	2069	2070
Sand %	44	34	32	26	26
Silt %	12	16	14	14	14
Clay %	44	50	54	60	60
Texture class	C	C	C	C	C
pH-H ₂ O 1:2½ suspension	8.8	9.6	9.0	8.7	8.9
pH-KCl 1:2½ "	6.9	7.4	7.4	7.5	7.4
EC (mmhos/cm) 1:2½	0.29	0.80	5.00	7.50	6.00
CaCO ₃ %	0.8	4.5	3.7	2.9	1.9
CaSO ₄ .2H ₂ O	tr	tr	tr	0.6	tr
C %	0.60	0.15	0.18	0.12	0.12
N %	0.06	-	-	-	-
Saturation %	-	-	49.0	101.6	83.4
ECe (mmhos/cm)	--	-	21.0	19.5	21.0
pH-paste	-	-	7.5	7.3	7.8
CEC (me/100g soil)	30.0	33.0	33.4	34.5	37.4
Exchangeable cations:					
Ca (me/100g soil)	50	53	48	33	32
Mg "	1.9	2.8	2.8	2.8	2.4
K "	3.0	1.3	1.3	1.1	1.0
Na "	1.2	9.2	20.3?	22.6?	22.7?
Base saturation	100+	100+	100+	100+	100+
ESP	4.0	28	61?	66?	61?
Qualitative CaCO ₃	++	+++	+++	+++	+++
Mehlich analysis:					
Available Na (me/100g soil)	0.82	6.60	-	-	-
" K "	0.96	0.10	-	-	-
" Ca "	17.4	19.4	-	-	-
" Mg "	10.4	9.2	-	-	-
" Mn "	1.25	0.08	-	-	-
" P (ppm) "	152	16	-	-	-

- A1 0-16cm Brown to dark brown (7.5YR 4/4 dry and moist) clay; weak, very fine crumb structure; slightly sticky and slightly plastic when wet; moderately calcareous and non-saline; clear and smooth transition to:
- B21 16-38cm Dark reddish brown (5YR 3/4 dry, 5YR 3/3 moist) clay; moderate to strong, coarse, prismatic structure breaking into moderate to strong, coarse to very coarse, angular blocky structure very hard when dry, firm when moist, sticky and plastic when wet; very few, fine pores; strongly calcareous and non-saline; clear and smooth transition to:
- B22 38-65cm Dark reddish brown (5YR 3/4 moist) clay; weak to moderate, coarse to very coarse, angular blocky structure breaking into weak, very fine to medium, angular blocky structure; consistence, slickensides and pores as above; very few CaCO_3 concretions, 2-4mm in size; strongly calcareous and strongly saline; gradual and smooth transition to:
- B23 65-85cm Dark brown (7.5YR 3/3 moist) clay; weak, coarse to very coarse, angular blocky structure; consistence as above; common, weak slickensides; few, very fine pores; CaCO_3 concretions, calcareousness, salinity and transition as above:
- B24sa 85-130cm Dark brown to very dark greyish brown (7.5YR 3/2 to 10YR 3/2 moist) clay; weak to moderate coarse to very coarse, angular blocky structure breaking into moderate very fine to fine, angular blocky structure; consistence and pores as above; common to abundant, weak slickensides; CaCO_3 concretions as above; moderately calcareous and strongly saline, with common, small clusters of NaCl- crystals.

Remarks: 1) on the ILACO - map this area is indicated as S2-soils
2) 2-5mm thick, weak surface sealing
3) few, scattered cracks at the surface

SOIL ANALYTICAL DATA

Chewele Branch Canal Research Area

Field Ref: Chew - 1

Unit S2

Depth in cm	0-19	19-35	35-58	58-100	100-125
Lab. No. /78	2031	2032	2033	2034	2035
Sand %	32	32	28	18	26
Silt %	18	12	14	20	14
Clay %	50	56	58	62	60
Texture class	C	C	C	C	C
pH-H ₂ O 1: 2½ suspension	9.0	9.1	9.2	9.0	8.9
pH-KCl 1:2½ suspension	7.4	7.8	7.9	7.8	7.8
EC (mmhos/cm) 1:2½ "	0.35	2.50	5.00	7.00	7.50
CaCO ₃ %	3.5	5.8	5.8	3.9	4.5
CaSO ₄ ·2H ₂ O	tr	0.02	tr	tr	0.02
C %	0.70	0.33	0.42	0.36	0.42
N %	0.06	-	-	-	-
Saturation %				91.7	
ECe (mmhos/cm)	-	7.00	23.0	24.0	28.0
pH-paste	-	8.1	8.3	8.2	7.7
CEC (me/100g soil)	32	37 ^x	37 ^x	37 ^x	37 ^x
Exchangeable cations:					
Ca (me/100g soil)	46	53	52	37	50
Mg "	2.8	2.9	3.3	2.5	4.0
K "	2.1	1.9	1.7	3.0	1.4
Na "	3.2	18.5?	14.4	20.0	18.6
Base saturation	100+	100+	100+	100+	100+
ESP	10	50?	39	54	50
Qualitative CaCO ₃	+++	+++	+++	+++	+++
Mehlich analysis:					
Available N _a (me/100g soil)	1.40	4.30	-	-	-
" K "	0.32	0.22	-	-	-
" Ca "	15.2	14.0	-	-	-
" Mg "	9.2	8.8	-	-	-
" Mn "	0.30	0.34	-	-	-
" P (ppm)	58	63	-	-	-

x = estimates

- A1 0-19cm Yellowish red (7.5YR 5/4 dry, 5YR 4/6 moist) clay; weak, very fine to fine, crumb structure; friable when moist, slightly sticky and slightly plastic when wet; 1-2% CaCO_3 concretions, 4-10mm in size; strongly calcareous and non-saline; clear and smooth transition to:
- B21 19-58cm Reddish brown (5YR 4/4 dry and moist) clay; moderate, coarse to very coarse, angular blocky structure breaking into weak to moderate, fine, angular blocky structure; hard when dry, firm when moist, sticky and plastic when wet; few, weak slickensides; few to common, very fine pores; 1-2% CaCO_3 concretions, 4-10mm in size; strongly calcareous and strongly saline; gradual and smooth transition to:
- B22 58-100cm Yellowish red (5YR 5/6 dry and moist) clay; moderate, coarse to very coarse, angular blocky structure breaking into weak to moderate, very fine to medium, angular blocky structure; very hard when dry, firm when moist, sticky and plastic when wet; few to common, weak slickensides; few to common, very fine pores; CaCO_3 concretions, calcareousness, salinity and transition as above;
- B23 100-125cm+ Yellowish red (5YR 5/6 dry and moist) clay; moderate coarse to very coarse, angular blocky structure breaking into weak to moderate, fine to medium angular blocky structure; very hard when dry, firm when moist, sticky and plastic when wet; common to abundant, weak slickensides; few, very fine and fine pores; CaCO_3 concretions, calcareousness and salinity as above.

Remarks: 1) this area is also indicated as S2 on ILACO - map
2) 1-2mm thick, weak to moderate, surface sealing

Appendix 2
REPRESENTATIVE PROFILES
OF THE
EXPERIMENTAL SITE
IN THE
HOLA IRRIGATION PROJECT

SOIL ANALYTICAL DATA

Field Ref.: I1

Hola Experimental Area

Unit S2c

Depth in cm	0-15	15-33	33-70	70-95	95-125
Lab. No./78	2051	2052	2053	2054	2055
Sand %	30	30	26	20	16
Silt %	16	12	12	18	14
Clay %	54	58	62	62	70
Texture class	C	C	C	C	C
pH-H ₂ O 1: 2½ suspension	9.0	8.8	8.9	9.0	8.9
pH-KCl 1: 2½ suspension	7.0	7.1	7.5	7.4	7.4
EC (mmhos/cm) 1:2½ "	0.40	1.25	4.0	5.5	5.5
CaCO ₃ %	2.3	4.3	4.5	3.6	2.8
CaSO ₄ .2H ₂ O %	tr	0.04	tr	tr	tr
C %	0.71	0.35	0.21	0.15	0.12
N %	0.10	0.06	-	-	-
Saturation %	-	84.2	71.5	79.9	90.7
ECe (mmhos/cm)	-	7.0	17.0	21.5	20.0
pH-paste	-	7.5	7.8	7.7	7.6
CEC (me/100g soil)	34.4	35 ^x	35 ^x	35 ^x	40 ^x
Exchangeable cations:					
Ca (me/100g soil)	53	56	56	50	50
Mg "	3.2	3.7	4.1	4.0	4.3
K "	1.8	1.2	1.7	1.7	1.6
Na "	2.8	8.5	9.2	24.8?	29.2?
Base saturation	100+	100+	100+	100+	100+
ESP	8.1	24	26	71?	73?
Qualitative CaCO ₃	+++	+++	+++	+++	+++
Mehlich analysis:					
Available Na (me/100g soil)	1.9	5.3	-	-	-
" K "	0.38	0.06	-	-	-
" Ca "	22.0	24.0	-	-	-
" Mg "	11.6	10.4	-	-	-
" Mn "	0.38	0.05	-	-	-
" P (ppm)	44	20	-	-	-

x = estimates

Mapping unit S2c

profile no. 11

- A1 0-15cm Dark reddish brown (7.5YR 3/3 dry, 5YR 3/4 moist) clay; weak, very fine to medium, crumb structure, slightly hard when dry, friable when moist, sticky and plastic when wet; many, very fine pores; slightly calcareous; about 1% CaCO_3 concretions, 2-4mm in size; clear and smooth transition to:
- B21 15-33cm Dark reddish brown (7.5YR 3/3 dry, 5YR 3/3 moist) clay; weak to moderate, coarse, angular blocky structure breaking into moderate, fine to medium, angular blocky structure; few, thin clayskins; very hard when dry, firm when moist, sticky and plastic when wet; few to common very fine and few fine pores; strongly calcareous, about 1% CaCO_3 concretions 2-4mm in size; slightly saline; gradual and smooth transition to:
- B22 33-70cm Dark reddish brown (5YR 3/4 dry and moist) clay; weak to moderate, coarse to very coarse, angular blocky structure breaking into weak to moderate, fine to medium, angular blocky structure; few, thin clayskins; very hard when dry, friable when moist, sticky and plastic when wet; few very fine to fine pores; strongly calcareous; about 1% CaCO_3 concretions 2-4mm in size; moderately saline; gradual and smooth transition to:
- B23sa 70-95cm Dark brown (7.5YR 4/2 dry, 7.5YR 3/2 moist) clay; weak to moderate, coarse to very coarse, angular blocky structure breaking into weak to moderate, very fine to medium, angular blocky structure; common, weak slickensides; very hard when dry, firm when moist, sticky and plastic when wet; few, very fine to fine pores; strongly calcareous; about 1% CaCO_3 concretions, 2-4mm in size; strongly saline with white crystals of NaCl ; gradual and smooth transition to:

B24 95-125cm+

Dark grey (10YR 4/2 dry, 10YR 4/1 moist) clay; moderate to strong, coarse to very coarse, angular blocky structure breaking into weak to moderate, very fine to medium, angular blocky structure; abundant, moderate to strong slickensides; very hard when dry, firm when moist, sticky and plastic when wet; few, very fine pores; strongly calcareous; 2-3 % CaCO_3 concretions, 1-2cm in size; strongly saline.

- Other remarks:
1. 3-4cm thick, brown to dark brown (10YR 5/4 dry, 7.5 YR 4/4 moist), weak crust
 2. cracks only in the profile pit
 3. rooting: 0-33cm: many very fine and few fine to coarse roots
33-125cm: very few, very fine roots

SOIL ANALYTICAL DATA

Field Ref. G5

Hola Experimental Area

Unit S2c

Depth in cm	0-14	14-25	25-42	42-92	92-114
Lab. No./78	2026	2027	2028	2029	2030
Sand %	38	36	34	30	22
Silt %	14	12	14	14	16
Clay %	48	52	52	56	62
Texture class	C	C	C	C	C
pH-H ₂ O 1: 2½ suspension	8.7	9.0	8.7	9.1	9.0
pH-KCl 1: 2½ "	6.9	7.3	7.4	7.9	7.7
EC (mmhos/cm) 1: 2½	0.30	0.65	2.90	4.50	6.50
CaCO ₃ %	0.7	3.0	5.8	5.9	6.2
CaSO ₄ .2H ₂ O %	tr	0.02	0.02	tr	tr
C %	0.61	0.67	0.59	0.50	0.53
N %	0.07	0.05	-	-	-
Saturation %	-	-	63.9	73.3	59.6
ECe (mmhos/cm)	-	-	13.0	14.5	16.0
pH -paste	-	-	7.8	7.8	8.0
CEC (me/100g soil)	26.0	28.0	34.5	37.8	37.4
Exchangeable cations:					
Ca (me/100g soil)	37	45	50	59	48
Mg "	2.8	3.3	3.3	3.0	3.2
K "	2.9	1.0	2.6	2.8	3.3
Na "	1.3	3.7	8.9	26.0?	29.8?
Base Saturation %	100+	100+	100+	100+	100+
ESP	5	13.1	26	69?	80?
Qualitative CaCO ₃	++	+++	+++	+++	+++
Mehlich analysis:					
Available Na(me/100g soil)	0.7	2.4	-	-	-
" K "	0.76	0.1	-	-	-
" Ca "	12.8	17.6	-	-	-
" Mg "	10.4	11.4	-	-	-
" Mn "	0.86	0.04	-	-	-
" P (ppm)	48	30	-	-	-

Mapping unit S2c

profile No. G5

- A1 0-14cm Dark reddish brown (5YR 4/4 dry, 5YR 3/4 moist) clay; weak, very fine to fine crumb; slightly hard when dry, very friable when moist, slightly sticky and slightly plastic when wet; about 1% CaCO₃ concretions, 2-5mm in size; slightly calcareous and non-saline; clear and smooth transition to:
- B1 14-25cm Dark reddish brown (5YR 3/4 dry, 5YR 3/3 moist) clay; moderate, medium, angular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; common very fine and few fine pores; strongly calcareous and non-saline; about 1% CaCO₃ concretions, 2-5mm in size; gradual and smooth transition to:
- B21 25-42cm Dark reddish brown (5YR 3/4 dry and moist) clay; moderate, medium, angular blocky structure; hard when dry, firm when moist, sticky and plastic when wet; common, very fine pores; soft lime and about 1% CaCO₃ concretions, 2-5mm in size; strongly calcareous and moderately saline; clear and smooth transition to:
- B22 42-92cm Dark reddish brown (5YR 3/4 dry and moist) clay; moderate, medium, angular blocky structure; very hard when dry, firm when moist, sticky and plastic when wet; few, thin clayskins and few, weak slickensides; few to common, very fine pores; soft lime, CaCO₃ concretions and strongly calcareous as above; strongly saline; gradual and smooth transition to:
- B23 92-115cm+ Dark reddish brown (5YR 3/4 dry, 5YR 3/3 moist) clay; structure; consistence, clayskins, slickensides and pores as above; about 1% CaCO₃ concretions, 2-5mm in size; strongly calcareous and strongly saline.

SOIL ANALYTICAL DATA

Field Ref. D4

Hola Experimental Area

unit N42

Depth in cm	0-10	10-30	30-62	62-108	108-125
Lab. No./78	2040	2041	2042	2043	2044
Sand %	42	36	7 30	24	22
Silt %	14	12	14	16	16
Clay %	44	52	56	60	62
Texture class	C	C	C	C	C
pH-H ₂ O 1:2½ suspension	8.8	9.4	9.6	9.3	9.4
pH-KCl 1:2½ "	7.4	7.6	7.5	7.9	7.8
EC (mmhos/cm) 1:2½	0.35	0.65	2.10	4.50	4.0
CaCO ₃ %	1.8	7.2	6.6	4.6	5.1
CaSO ₄ .2H ₂ O %	tr	0.02	tr	tr	0.01
C %	0.97	0.59	0.67	0.53	0.36
N %	0.10	0.05	-	-	-
Saturation %	-	-	105.0	84.3	116.6
ECe (mmhos/cm)	-	-	8.50	14.0	13.0
pH-paste	-	-	7.7	7.6	7.9
CEC (me/100g soil)	34.6	34.2	36.6	39.8	40.5
Exchangeable cations:					
Ca (me/100g soil)	11.2	50	42	58	40
Mg "	6.8	4.0	3.8	3.5	3.4
K "	2.7	1.0	1.5	1.5	1.5
Na "	1.7	10.5	18.1	32.5?	32.6?
Base saturation %	100+	100+	100+	100+	100+
ESP	4.9	31	49	65?	80?
Qualitative CaCO ₃	++	+++	+++	+++	+++
Mehlich analysis:					
Available Na(me/100g soil)	0.72	4.5	-	-	-
" K "	0.78	0.07	-	-	-
" Ca "	22.0	27.0	-	-	-
" Mg "	11.2	10.4	-	-	-
" Mn "	0.88	0.02	-	-	-
" P (ppm)	66	11	-	-	-

Mapping unit N42

profile No. D4

- A1 0-10cm Dark reddish brown (5YR 4/4 dry, 5YR 3/4 moist) clay; weak, very fine to fine, crumb structure; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; many, very fine pores; moderately calcareous and non-saline; clear and smooth transition to:
- B21 10-62cm Dark reddish brown (5YR 3/4 dry, 5YR 3/3 moist) clay; moderate, coarse to very coarse, prismatic structure breaking into moderate, medium to coarse, angular blocky structure; very hard when dry, firm when moist sticky and plastic when wet; few, very fine pores; strongly calcareous and saline; clear and smooth transition to:
- B22 62-108cm Brown to dark brown (7.5YR 4/4 moist) clay; moderate, medium to coarse, angular blocky structure; few, weak clay skins or slickensides; very hard when dry, firm when moist, sticky and plastic when wet; few, very fine pores; strongly calcareous and saline; clear and wavy transition to:
- B23ca 108-125cm+ Brown to dark brown (7.5YR 4/4 + 4/2 moist) clay; moderate, medium, angular blocky structure; common, strong slickensides; very hard when dry, firm when moist, sticky and plastic when wet; few, very fine pores; moderately to strongly calcareous and saline; much soft lime.

Other remarks:

1. hard CaCO_3 concretions (2-3mm) from surface downward
2. soft lime from B21 downward; present in great quantities in B23
3. few cracks at surface but many in the profile
4. 2-3cm thick, weak surface crust
5. rooting: 0-40cm: common, very fine and very few, fine to coarse roots; 40cm+: very few, very fine roots

SOIL ANALYTICAL DATA

Field Ref.:G1

Hola Experimental Area

Unit N42

Depth in cm	0-12	12-30	30-47	47-67	67-100	100-115
Lab. No./78	2020	2021	2022	2023	2024	2025
Sand %	32	28	26	24	18	16
Silt %	18	16	14	14	16	18
Clay %	50	56	60	62	66	66
Texture class	C	C	C	C	C	C
pH-H ₂ O 1:2½ suspension	8.7	9.3	9.4	9.4	9.6	9.5
pH-KCl 1:2½ "	7.1	7.1	7.9	7.9	7.7	6.9
EC (mmhos/cm) 1:2½	0.35	0.60	1.20	1.95	1.80	2.60
CaCO ₃ %	3.4	4.5	5.1	4.6	4.2	3.1
CaSO ₄ .2H ₂ O %	tr	0.04	tr	tr	tr	tr
C %	0.72	0.43	0.52	0.40	0.59	0.47
N %	0.07	0.05	-	-	-	-
Saturation %	-	-	-	-	-	-
ECe(mmhos/cm)	-	-	-	6.5	-	8.0
pH-paste	-	-	-	8.1	-	8.6
CEC(me/100g soil)	37.2	37.8	35.5	37.6	37.9	37.5
Exchangeable cations:						
Ca (me/100g soil)	47	40	53	37	41	29
Mg "	3.3	4.0	3.9	4.0	3.4	2.7
K "	2.8	1.4	1.8	1.7	1.9	1.8
Na "	1.8	7.6	12.8	22.5?	25.6?	29.0?
Base saturation %	100+	100+	100+	100+	100+	100+
ESP	5.0	20	36	60?	68?	77?
Qualitative CaCO ₃	+++	+++	+++	+++	+++	+++
Mehlich analysis:						
Available Na (me/100g soil)	0.78	2.2	-	-	-	-
" K "	0.4	0.14	-	-	-	-
" Ca "	24.0	16.0	-	-	-	-
" Mg "	10.0	8.6	-	-	-	-
" Mn "	0.23	0.28	-	-	-	-
" P (ppm)	34	30	-	-	-	-

A1 0-12cm

Dark reddish brown (5YR 3/4 both dry and moist) clay; weak, fine to medium, crumb structure; slightly hard when dry, friable when moist, sticky and plastic when wet; many very fine pores; strongly calcareous and non-saline; about 2% CaCO_3 concretions; clear and smooth transition to:

B21 12-47cm

Dark reddish brown (5YR 3/4 both dry and moist) clay; weak, coarse to very coarse, prismatic structure breaking into moderate, coarse to very coarse, angular blocks which in turn break into moderate, fine to medium angular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; few, very fine to fine pores; strongly calcareous; about 1% CaCO_3 concretions; non-saline; clear and smooth transition to:

B22 47-67cm

Dark reddish brown (5YR 3/4 moist) clay; moderate, coarse to very coarse angular blocky structure; few, thin clay skins and few, weak slickensides; very hard when dry, firm when moist, sticky and plastic when wet; few, very fine pores; strongly calcareous; about 1% CaCO_3 concretions; slightly saline; clear and smooth transition to:

B23 67-100cm

Dark reddish brown (5YR 3/4 moist) clay; weak, coarse to very coarse, angular blocky structure; few, weak slickensides and few, thin clay skins; very hard when dry, firm when moist; sticky and plastic when wet; few, very fine pores; strongly calcareous; about 1% CaCO_3 concretions; slightly saline; clear and smooth transition to:

B24 100-115cm +

Dark brown (7.5YR 3/3 moist) and dark greyish brown (10YR 4/2 moist) clay; weak, coarse to very coarse, angular blocky structure; few, weak slickensides;

very hard when dry, firm when moist, sticky and plastic when wet; few very fine pores; strongly calcareous; about 1% CaCO_3 concretions; moderately saline.

Other remarks:

- 1) Scattered, very few cracks; no sealing
- 2) Rooting: 0-30cm: many, very fine and very few roots
30-67cm: very few, very fine roots

SOIL ANALYTICAL DATA

Field Ref.:A5

Hola Experimental Area

Unit N42-N3

Depth in cm	0-15	15-30	30-45	45-90	90-140
Lab. No./78	2061	2062	2063	2064	2065
Sand %	38	38	26	28	44?
Silt %	10	10	14	10	10
Clay %	52	52	60	62	46?
Texture class	C	C	C	C	C
pH-H ₂ O 1:2½ suspension	8.9	9.3	9.2	7.4	9.2
pH-KCl 1:2½ "	7.7	7.0	7.2	7.5	7.7
EC (mmhos/cm) 1:2½	0.30	0.55	2.95	5.0	4.0
CaCO ₃ %	1.1	5.7	7.4	7.2	4.0
CaSO ₄ .2H ₂ O %	0.2	tr	0.04	tr	tr
C %	0.38	0.29	0.12	0.09	0.18
N %	0.08	0.05	-	-	-
Saturation %	-	-	60.8	79.7	122.4
ECe (mmhos/cm)	-	-	8.0	14.5	15.5
pH-paste	-	-	7.9	7.2	8.2
CEC (me/100g soil)	23.5	24.3	26.4	29.4	29.4
Exchangeable cations:					
Ca (me/100g soil)	59	54	58	49	32
Mg "	2.6	4.0	4.0	4.3	4.0
K "	2.5	1.1	1.3	1.5	1.4
Na "	1.3	6.4	9.9	19.6?	24.6?
Base saturation%	100+	100+	100+	100+	100+
ESP	5.5	26	38	67?	84?
Qualitative CaCO ₃	+++	+++	+++	+++	+++
Mehlich analysis:					
Available Na (me/100g soil)	1.18	3.7	-	-	-
" K "	0.78	0.09	-	-	-
" Ca "	17.6	26.0	-	-	-
" Mg "	12.4	11.6	-	-	-
" Mn "	1.0	0.02	-	-	-
" P (ppm)	66	9.0	-	-	-

Mapping unit N42-N3

profile No.A5

- A1 0-15cm Dark reddish brown (7.5YR 4/4 dry, 5YR 3/4 moist) clay; weak, fine to medium crumb structure; slightly hard when dry, friable when moist, sticky and plastic when wet; many, very fine and few, fine to medium pores; moderately calcareous and non-saline;
- B21 15-45cm Dark reddish brown (5YR 3/3 both dry and moist) clay; moderate, coarse prismatic structure breaking into moderate, coarse, angular blocky structure; hard when dry, friable when moist, sticky and plastic when wet; common to many, very fine and few, fine to medium pores; strongly calcareous; 2% soft lime; slightly saline;
- B22 45-90cm Reddish brown (5YR 3/4 dry, 5YR 4/4 moist) clay; weak, very coarse, prismatic structure breaking into moderate, coarse to very coarse, angular blocks which in turn break into moderate, fine to medium, angular blocks; few, weak slickensides or clay skins; hard when dry, firm when moist, sticky and plastic when wet; common, very fine pores; 1% CaCO₃ concretions; strongly calcareous and moderately saline;
- B23 90-140cm + Brown to dark brown (7.5YR 4/4 dry, 7.5YR 4/2 moist) clay; weak to moderate, coarse to very coarse, angular blocky structure; common, weak slickensides; very hard when dry, firm when moist, sticky and plastic when wet; few, very fine pores; strongly calcareous and strongly saline.
- Other remarks: 1. Rooting: 0-15cm: ~~many~~ very fine and few fine and medium roots
15-45cm: common, very fine and few, fine and medium roots
45cm+: very few, very fine and fine roots
2. 5cm thick, light yellowish brown (10YR 6/4 moist), massive crust, with few, very fine pores; non-calcareous.

Mapping unit N42ab-N3

profile No.C5

- A1 0-11cm Brown to dark brown (7.5YR 4/4 dry, 7.5YR 3/4 moist) clay loam to clay; porous massive to weak, very fine to fine, crumb structure; slightly hard when dry, friable when moist, slightly sticky and slightly plastic when wet; many very fine pores; moderately calcareous and non-saline; clear and smooth transition to:
- B1 11-30cm Dark reddish brown (5YR 3/4 dry, 5YR3/3 moist) clay; weak, fine to medium angular blocky structure; slightly hard when wet; few to common, very fine pores; strongly calcareous and non-saline; clear and smooth transition to:
- B21 30-65cm Dark reddish brown (5YR 3/4 dry and moist) clay; weak, fine to medium, angular blocky structure; few, thin clay skins; hard when dry, firm when moist, sticky and plastic when wet; few to common very fine pores; strongly calcareous and slightly saline; soft lime and few NaCl crystals; clear and wavy transition to:
- B22 65-80cm Brown to dark brown (7.5YR 4/2 moist) clay; moderate, medium, angular blocky structure; few, thin clay skins; hard when dry, firm when moist, sticky and plastic when wet; common, very fine pores; strongly calcareous and slightly saline; soft lime and few NaCl crystals; gradual and smooth transition to:
- B23 80-100cm Brown to dark brown(7.5YR 4/2 moist)clay; moderate medium, angular blocky structure; few to common, thin clay skins; hard when dry, firm when moist, sticky and plastic when wet; common, very fine pores; strongly calcareous and slightly saline; soft lime and many NaCl crystals; gradual and smooth transition to:

B24 100-120cm

Brown to dark brown (7.5YR 4/2 moist) clay; moderate, medium, angular blocky structure; hard when dry, firm when moist, sticky and plastic when wet; few to common pores; strongly calcareous and slightly saline.

Other remarks:

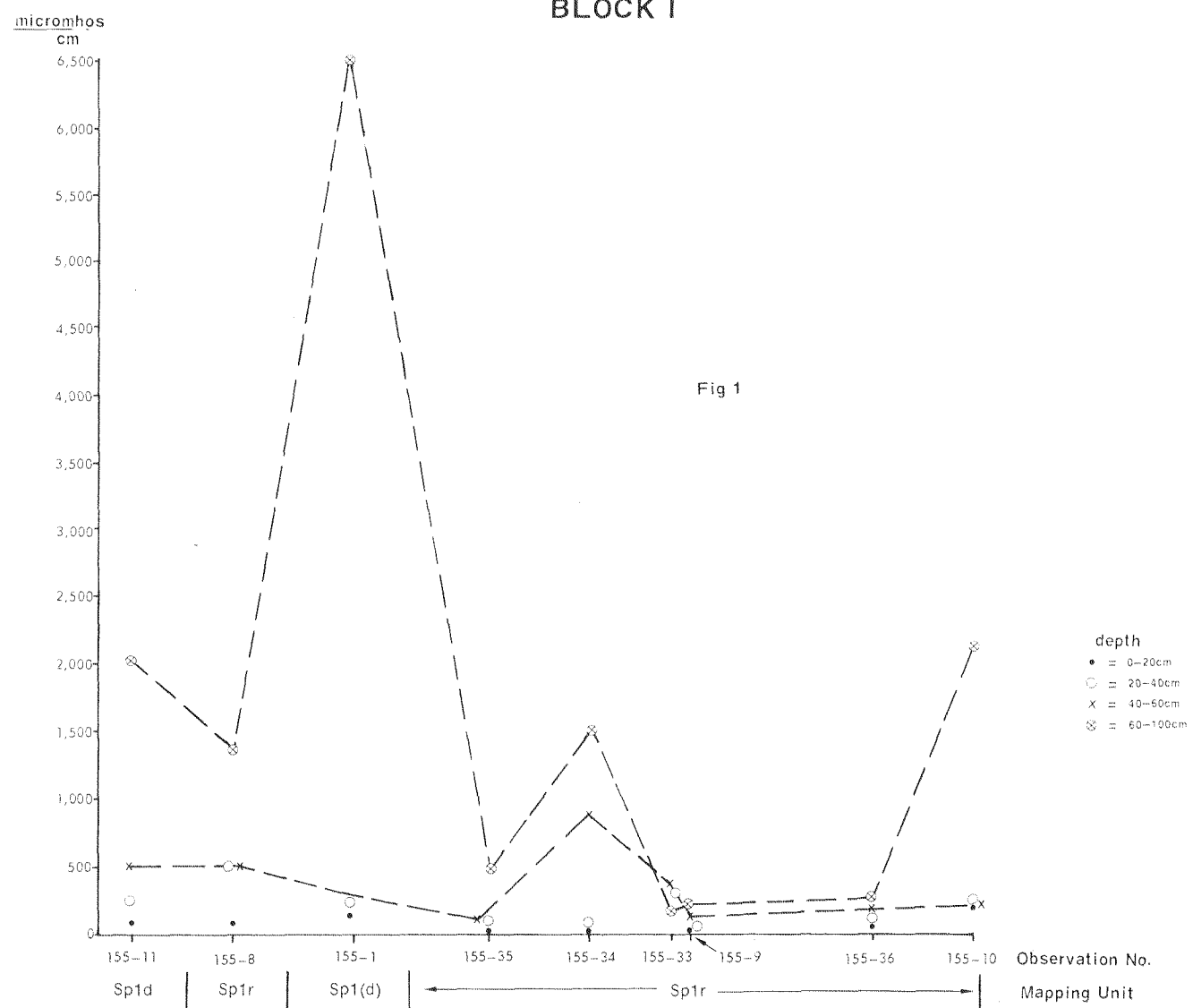
1. 2-3cm thick, moderately strong crusting
2. Rooting: 0-11cm: common, very fine roots
11-30cm: few, very fine roots
30cm+ no roots
3. 100% sand overwash cover

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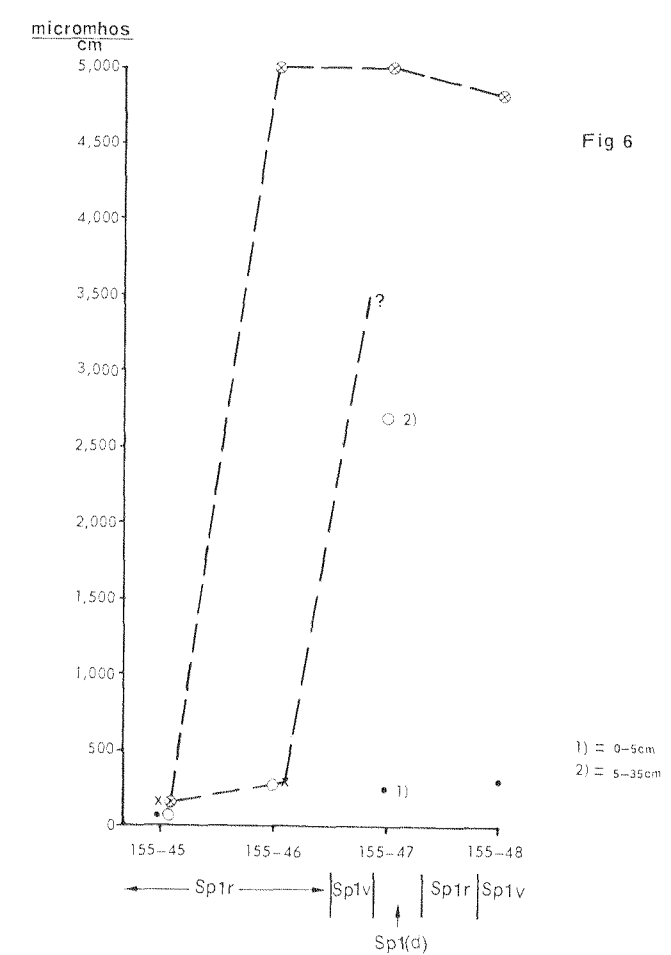
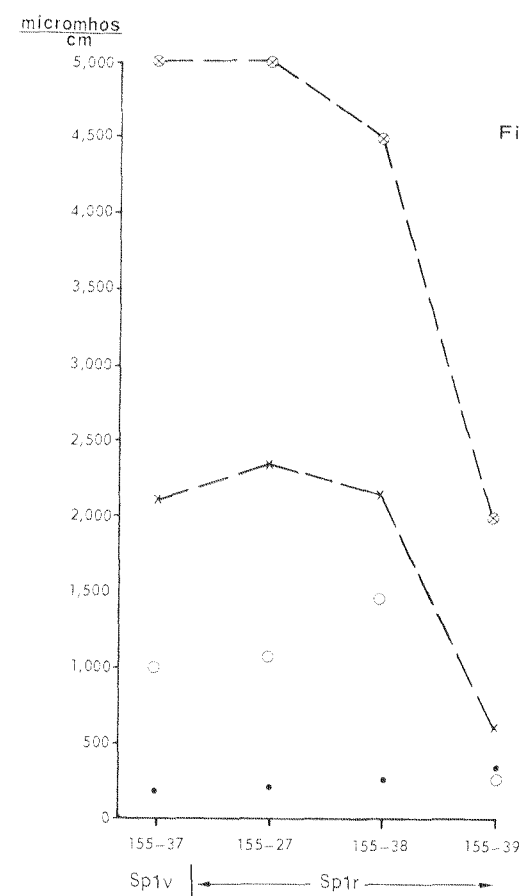
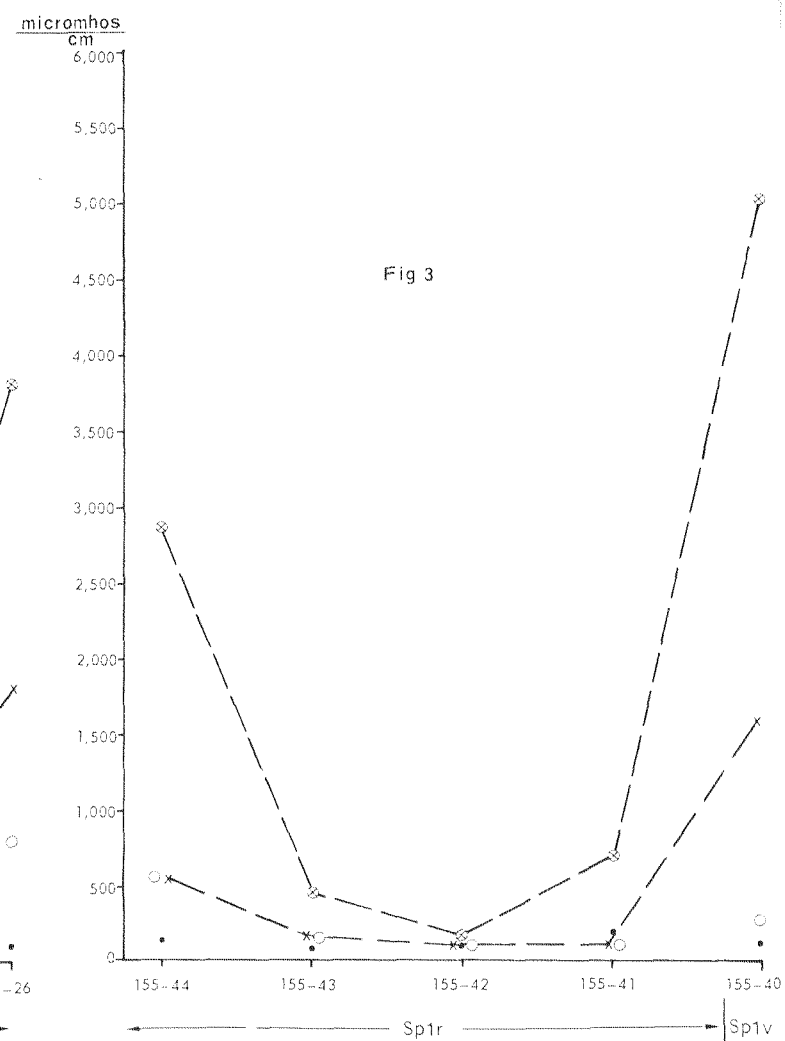
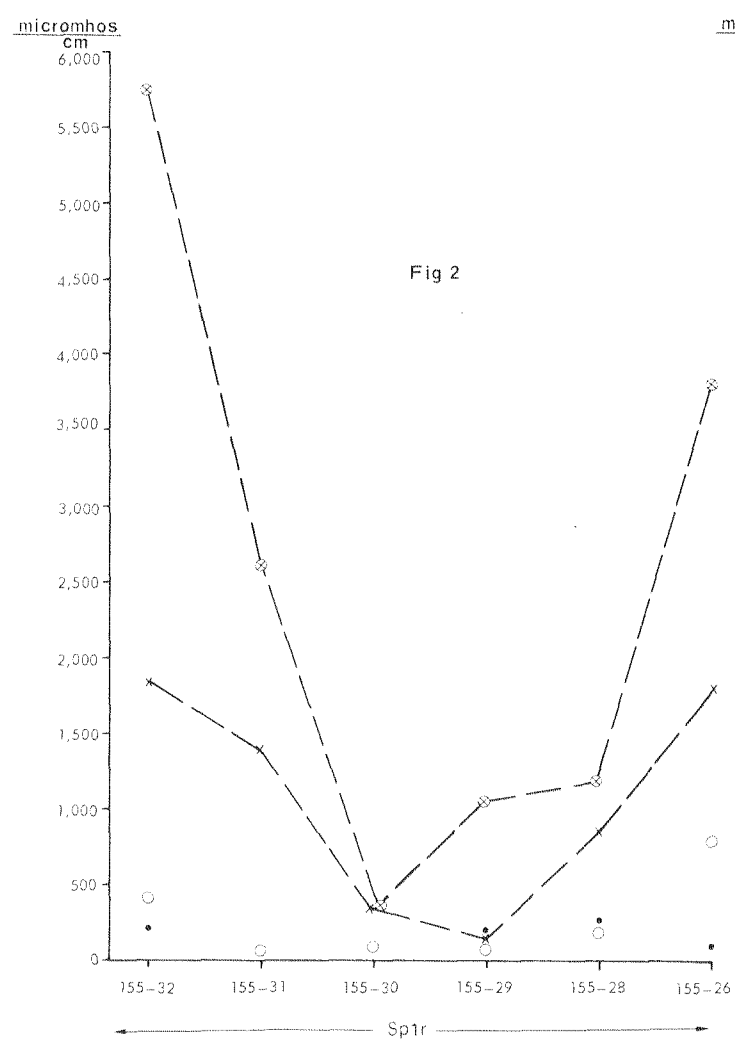
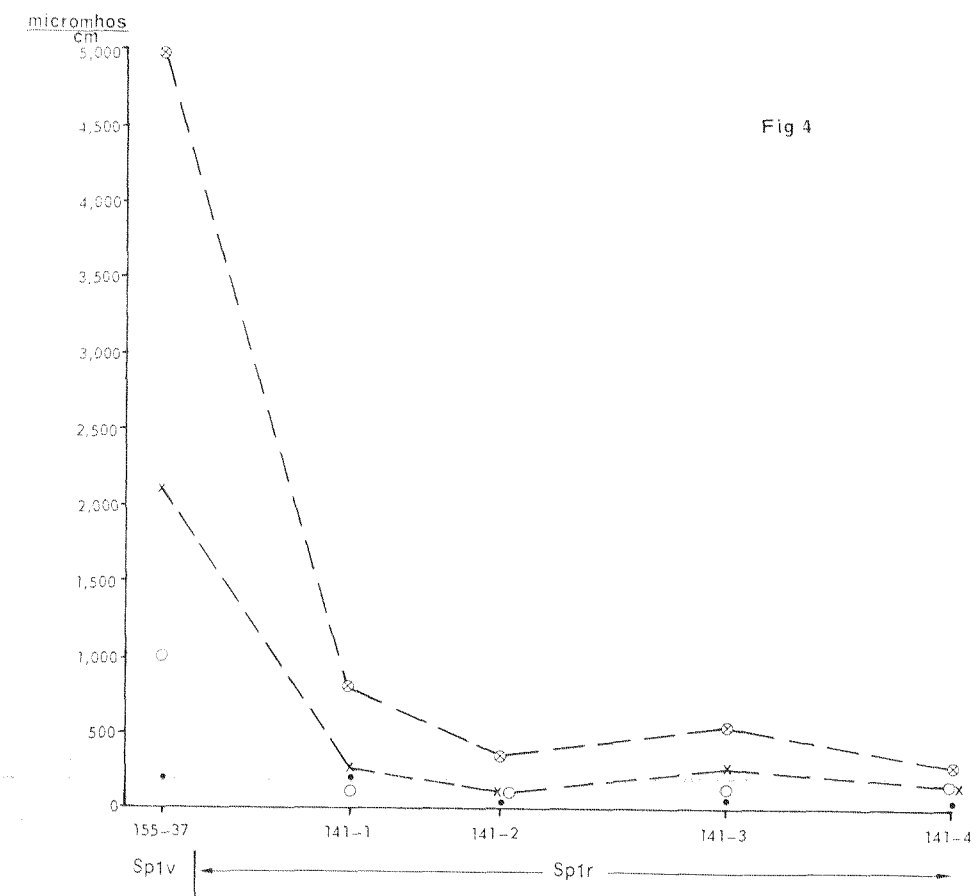
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FARENA IRRIGATION DEVELOPMENT AREA

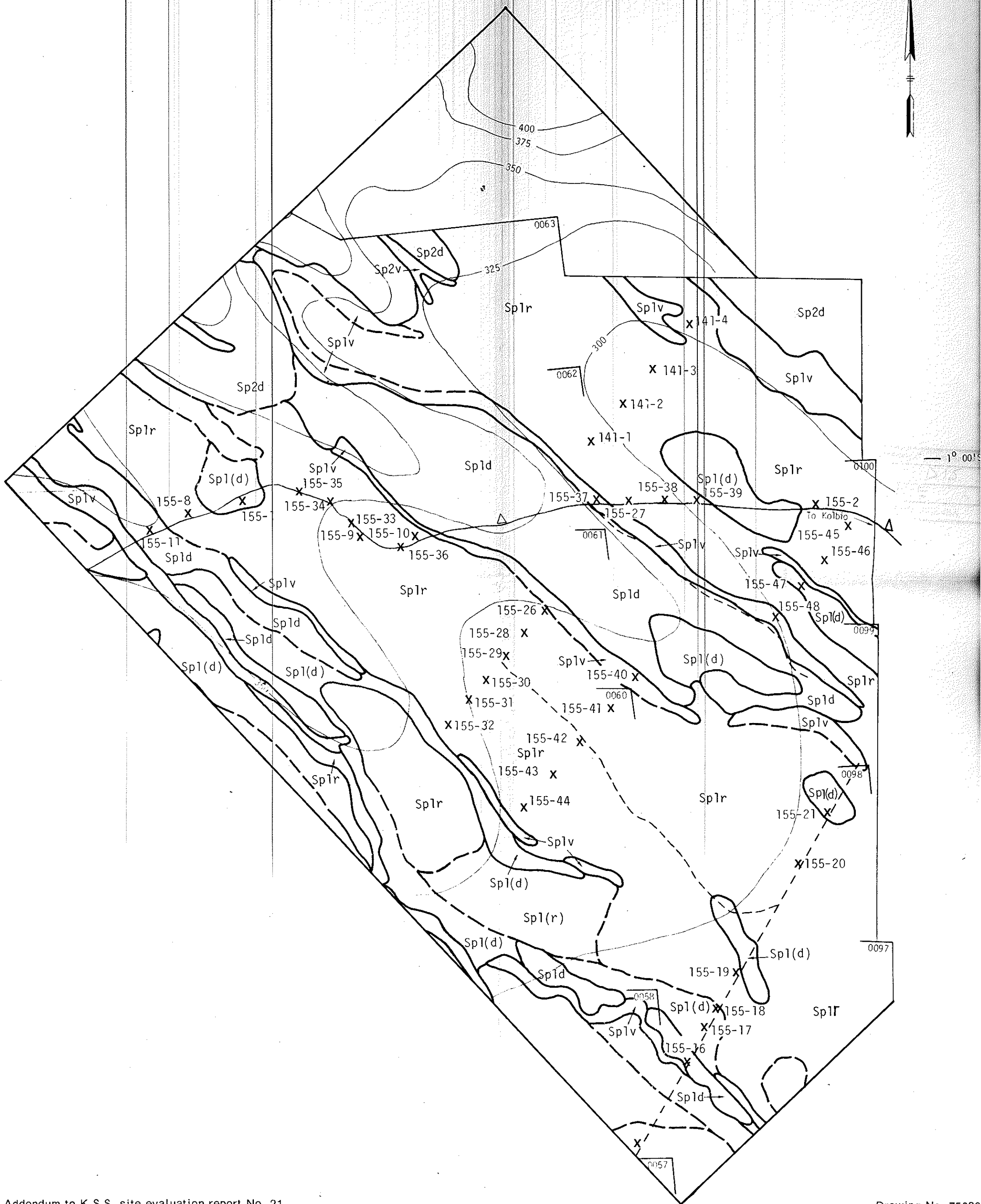
BLOCK I



BLOCK II



PART OF BURA - EAST PROVISIONAL SOIL MAP (FARENA IRRIGATION DEVELOPMENT AREA)



Extension site evaluation No. 21 (Bura East)

